BISMUTH

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Bismuth was last produced domestically, as a byproduct of lead refining, at a Nebraska refinery that closed in 1997. The last stocks of bismuth held in the National Defense Stockpile (NDS) were sold that same year. In 2003, all primary bismuth consumed in the United States was imported. Only a small amount of bismuth was obtained by recycling old scrap. The largest foreign producers of refined bismuth in 2003, in decreasing order of production, were Mexico, Belgium, China, and Peru. The Belgian producer, however, only refined bismuth from imported concentrates.

Bismuth consumption in the United States decreased almost 10% during 2003, compared with that of 2002. As a result of an ongoing U.S. Geological Survey (USGS) analysis of the bismuth market begun in 2003, end use patterns for 2003 contain different assumptions than in previous years. The domestic consumption of bismuth for 2003 was about 39% for metallurgical additives in alloying and galvanizing; 31% for bismuth alloys, fusible alloys, solder, and ammunition; 29% for chemical and pharmaceutical uses; and 1% for research and other uses (table 2).

In recent years, several new uses for bismuth have been developed as a nontoxic substitute for lead. These include the use of bismuth in brass plumbing fixtures, fire assaying, ceramic glazes, crystal ware, fishing weights, shot for waterfowl hunting, lubricating greases, pigments, and solders. According to the Bismuth Producers Association (Brussels, Belgium), the additional use of bismuth in galvanizing baths is anticipated as a replacement for lead. Bismuth in the bath allows the galvanization to be thinner and more even, with less accumulation on edges. Poor drainage results in the accumulation of galvanizing alloy in corners and angles and the bridging of small holes and narrow channels—thus requiring extra cleaning of the workpiece. Reduced accumulation avoids edge growths, which break off and allow rusting to begin. Zinc-bismuth alloys provide the same drainage properties as zinc-lead alloys without the toxicity of lead (Gagne, 2000; Yves Palmieri, Secretary General, Bismuth Producers Associations, oral commun., August 6, 2003).

The average annual New York dealer price for bismuth continued its downward trend, falling to $2.87 per pound in 2003 from $3.14 per pound in 2002 (table 1). The average annual price had been fairly steady from 1999 through 2001, with the typical bismuth price cycle consisting of long declines followed by fairly steep increases. Since 2001 the price has been steadily dropping to its lowest level since 1993. The value of bismuth consumed domestically in 2003 was about $13.4 million. Thus, with the combination of a decrease in consumption and the price decline, the value of the bismuth consumed decreased by almost 17% compared with the value consumed in 2002. Experts agree that bismuth has had a lackluster performance as compared with other metals in 2003. Although it has seen increased usage as lead replacements, pigments, and additives, it lacks a large dynamic end use that can pull up the price, as in the case with other metals. Another reason is the abundant supply of bismuth from China (Metal-Pages, 2004a§[1]).

Legislation and Government Programs

The Defense Logistics Agency, which administers the NDS, sold the last remaining bismuth in the stockpile in 1997.

The Safe Drinking Water Act Amendments of 1996 (Public Law 104-182) have banned lead from all fixtures, fluxes, pipes, and solders used for the installation or repair of facilities providing potable drinking water since 1998. The ban prompted a conversion to plumbing alloys that contain bismuth rather than lead. Increased use of plastic pipe, however, has kept the use of bismuth-alloyed brasses from growing more rapidly in plumbing applications.

The U.S. Environmental Protection Agency (EPA) has begun to enforce new standards limiting dangerous levels of lead on painted indoor surfaces, in dust, and on bare soils where children play. The standards provide uniform benchmarks for remedial action to safeguard the public from exposure to lead. These standards are expected to further the use of bismuth as a lead substitute (U.S. Environmental Protection Agency, 2000).

EPA, in coordination with industry, is preparing life-cycle studies of lead-free solders. Industry experts believe U.S. industry must respond to impending restrictions in a competitive and timely manner, identifying viable alternatives to traditional lead-tin solders or risk losing as much as $240 billion in revenues during a 3-year period. One of the lead-free solder alternatives being considered contains 3.3% bismuth (U.S. Environmental Protection Agency, 2002§).

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[1]References that include a section mark (§) are found in the Internet References Cited section.

Production

Domestic production of primary bismuth ceased in 1997. Some domestic firms continued to recover secondary bismuth from fusible alloy scrap in 2003, but secondary production data were not available. Secondary production was estimated to be less than 5% of domestic supply during the year.

Consumption

The USGS surveys domestic bismuth consumption annually. The amount used by nonrespondents is estimated on the basis of reports from prior years or on information from other sources.

Reported bismuth consumption was about 2,120 metric tons (t) in 2003, a 10% decrease from that of 2002 (table 1). As previously mentioned, the USGS is currently reevaluating the bismuth market; therefore, the full yearend use patterns for 2003 contain different assumptions than those in previous years. Reported consumption decreases in bismuth alloys and other uses (chemicals, cosmetics, and pharmaceuticals) were caused by the reassessment. The only major category that showed any increase was the metallurgical additives. This was also in part a result of the reassessment.

Bismuth, although having the crystal structure of a semimetal, is often considered a metal. This crystal structure, along with several of its other salient properties makes it an ideal substitute for lead in extreme-pressure additives. These unique salient properties include expansion on solidification, widest range between melting and boiling points, and lowest thermal and heat conductivity. Bismuth is the most diamagnetic of all metals, the least toxic, and has lowest absorption for neutrons; bismuth is also characterized as "soft," like lead (Rohr, 2000).

Bismuth pharmaceuticals include the well-known bismuth subsalicylate, the active ingredient in over-the-counter stomach remedies and other bismuth medicinal compounds used to treat burns, intestinal disorders, and stomach ulcers in humans and animals. Bismuth nitrate is the initial material used for the production of most bismuth compounds. Other applications of bismuth chemicals and compounds include uses in superconductors and pearlescent pigments for cosmetics and paints.

Bismuth metal is used primarily as a major constituent of various alloys and as a metallurgical additive (table 2). One class of bismuth alloys consists of the fusible (low-melting-point) alloys-combinations of bismuth with other metals, such as cadmium, gallium, indium, lead, and tin. Applications for these alloys include fuel tank safety plugs; holders for lens grinding and other articles for machining or grinding; solders; and fire sprinkler triggering mechanisms.

In addition to the lead-free solder noted above, bismuth has long been a substitute for the lead added to steel to provide greater machinability. A major domestic steel company began to use a bismuth-containing substitute for the leaded alloy nearly 20 years ago. Although bismuth has been successful in replacing lead in various applications, it has been challenged as a lead substitute by tin and tungsten (Cusack, 1999). Bismuth is also added in small amounts to aluminum and copper alloys to improve machinability. Further, it is added to malleable iron to prevent the formation of graphite flakes. These uses constitute the traditional metallurgical additives category.

Prices

The New York dealer price for commercially pure bismuth, published by Platts Metals Week, averaged about $2.87 per pound in 2003, representing a 9% ($0.27) decrease, compared with the average for 2002 (table 1). The price range was $2.70 to $3.10 per pound at the beginning of 2003. The price dipped slightly in mid-February, but by the end of mid-April, the price rebounded to that of the beginning of the year. In late July, the price range narrowed to $2.80 to $3.10 per pound. During the first week in October, the price range dropped and widened to $2.65 to $2.95 per pound. The following week the price range dropped slightly to $2.60 to $2.90 per pound and remained steady for the rest of the year.

Trade

Bismuth exports decreased in weight and increased in value in 2003 compared with those of 2002. Notable decreases were seen in exports to Canada, Malaysia, Netherlands, Peru, and the United Kingdom (UK). Canada and the UK saw large drops in imports from the United States in weight but not in value. Belgium and Japan increased imports from the United States dramatically owing to the effort to reduce the amount of lead used in solders (table 3).

Total U.S. bismuth imports increased 19.9% by weight and 18.2% by value in 2003 compared with the prior year's figures (table 4). Notable increases were seen in imports from Belgium, China, Germany, Hong Kong, and the Netherlands. These were offset to a minor extent by decreases in imports from Canada, Japan, and Peru.

World Review

Throughout most of the world, bismuth is a byproduct of processing lead ores; in China, it is a byproduct of tungsten ore processing. The Tasna Mine in Bolivia, the only mine that produced bismuth from a bismuth ore, has been on standby since the mid-1990s awaiting a significant rise in the metal price.

World refinery production of bismuth increased 5% in 2003 (table 5). China was the leading supplier of bismuth and became more cost efficient in its production in order to offset rising power and transport costs. Although there were no mining restrictions or raw materials shortages, reduction in smelter capacity reportedly continued to affect metal output (Metal Bulletin, 2003a). Industry sources have estimated that about one-third of the smelters in China closed in the first quarter of 2003, due to high operating costs and low international prices. Some of these smelters went bankrupt and it was anticipated that more than one-half of the production lost would not come back onstream (Metal Bulletin, 2003b). Efforts by China to charge higher prices for bismuth failed because buyers had no problem sourcing material at existing price levels (Metal-Pages, 2004a§).

Hunan Shizhyuan Nonferrous Metals Co., Ltd. (China) planned to maintain bismuth production at 600 t in 2003 with two-thirds of the total output for export (Platts Metals Week, 2003b). Bismuth metal production capacities for China's major producers are Hunan Shizhyuan—700 metric tons per year (t/yr); The Jinwang Group—400 t/yr; and Jiangxi Rare Metals & Rare Earth Tungsten Group Corp.—300 t/yr (Metal Bulletin, 2003b).

Yuguang Gold and Lead Co. Ltd., China's largest electrolytic lead producer, announced that it had upgraded its waste processing facilities and was now recovering bismuth from slag (Metal-Pages, 2003g§).

Cía. Doe Run Perú increased production of bismuth to 769 t to offset loss of revenue from copper in fiscal year 2003. The higher output represents a production increase of 35%. The company had plans to further increase production of bismuth to more than 1,000 t in fiscal year 2004 (Mining Journal, 2003a). These increases represent improvements to processes and metallurgical recovery, rather than construction of new capacity (Metal-Pages, 2003b§).

Industrias Peñoles, S.A. de C.V. (Mexico), the largest single producer of bismuth in the world, produced 788 t of bismuth in the first three quarters of 2003. At this rate, Peñoles would be slightly short of its 2002 bismuth production of 1,103 t. Lack of lead concentrates in 2003 forced the company to rely on outside sources of feed material (Industrias Peñoles, S.A. de C.V., 2004§).

Japan continued to import increasing quantities of bismuth as it led worldwide efforts to reduce the use of lead and cadmium in soldering, plumbing, and metal alloys. Bismuth was also being used to a greater extent in the Japanese industrial oil sector and as a cheaper alternative to organic compounds in pigments (Metal-Pages, 2003a§). According to the Bismuth Producers Association, Japan was making additional use of bismuth, along with selenium, in lead-free brasses. The forecast use is for several hundred tons per year of bismuth in this application alone (Yves Palmieri, Secretary General, Bismuth Producers Association, written commun., November 17, 2003).

Teck Cominco Limited's (Canada) 2003 production and sales of byproduct bismuth increased from 2002 levels, which reflected lost production in 2001-02 owing to plant shutdowns (Metal-Pages, 2003d§).

According to the Bismuth Producers Association, the use of bismuth in pigments made Ciba Specialty Chemicals (Switzerland) and BASF Aktiengesellschaft (Germany) the top consumers of bismuth in Europe. Additionally, Mexico increased its domestic consumption of bismuth in the galvanizing of steel and the production of bismuth salts (Yves Palmieri, Secretary General, Bismuth Producers Association, oral commun., January 23, 2004).

Several bismuth-containing deposits were in varying stages of mining feasibility review. Roscoe Postle Associates Inc. prepared an independent technical report on the Bonfim gold/tungsten project in Brazil's Rio Grande do Norte State for Verena Minerals Corp. (Canada). Their report, based on assays of bismuth, gold, and tungsten, recommended additional exploration, including diamond drilling, geological mapping, and continuous channel sampling of previous mining areas (Verena Minerals Corporation, 2003§).

Fortune Minerals Limited (Canada) drilled a total of 219 holes, 35 of them in 2003, in its NICO gold-cobalt-bismuth deposit near Yellowknife, Northwest Territories, Canada. The drilling program exceeded expectations with a number of high-grade intersections, some of which remain open for future expansion of reserves (Metal-Pages, 2003c§). This drilling program was expected to confirm continuity of the ore in this area and to contribute positively to the feasibility study scheduled for completion in 2004 (Fortune Minerals Limited, 2003a, b). The company announced successful completion of a $2.6 million financing package, part of which will fund feasibility studies for the NICO deposit (Fortune Minerals Limited, 2003c).

Tiberon Minerals Ltd. (Canada) completed a metallurgical test program to enhance bismuth recovery from its 70%-owned Nui Phao tungsten polymetallic deposit in Vietnam, near the Chinese border. The test work suggested that an enhanced bismuth recovery of 50% was possible, which would allow bismuth metal production to reach 1,750 t/yr (Platts Metals Week, 2003a). Tiberon announced completion of financing for a bankable feasibility study, which included engineering, pilot plant metallurgical studies, detailed geotechnical studies, and a final environmental impact assessment. Expectations are that the bankable feasibility study will be completed by the end of 2004 at what may possibly become both the world's largest tungsten mine and the world's largest bismuth mine. Tiberon also submitted the Investment License Application to the Vietnam government (Platts Metals Week, 2003c; Tiberon Minerals Ltd., 2003a§-c§).

Current Research and Technology

In the European Union (EU), Japan, and the Republic of Korea, researchers continued to develop system solutions for advanced and sustainable lead-free soldering. The Next Generation Environment-Friendly Soldering Technology (EFSOT) effort is an 11-million-euro project utilizing 132 person-years of research to investigate lead-free soldering technologies. As described in an EFSOT presentation, almost 60% of the effort will be expended on the upgrading of soldering technology as well as new material and process technology; another 20% of the effort will investigate the biological impacts of soldering materials; slightly less than 10% of the effort will be to examine the environmental impact, including evaluations of resource depletion and metal toxicity issues; and the final stage, requiring somewhat greater than 10% of the effort, will be to investigate recycling and component recovery (EFSOT, 2004§). Work performed by EFSOT scientists on oral and intratracheal toxicity and the carcinogenicity of lead-free metals was released. This preliminary study showed bismuth to have acute or single dose toxicity equal to that of antimony, indium, lead, and silver. The oral "no observed affect level" or chronic toxicity level, however, was very low. Intratracheal administration of bismuth to laboratory rats showed no effects on measured indicators. Bismuth was found not to be mutagenic in initial tests, and therefore probably, not carcinogenic, and on a chromosome aberration test the metal showed mutagenicity in only 6% of the tests with a dose of 5 grams per milliliter (Sato and others, 2004§). The European portion of a study analyzing the biological impact, environmental effects, and recycling criteria is planned for completion in September 2005 (EFSOT, 2004§).

A recent survey showed that the Japanese electronics industry was still behind the schedule set by the Japan Electronics and Information Technology Industries Association (JEITA), which called for a 50% conversion to lead-free solders by 2002. The lack of a standardized method for evaluating the reliability of lead-free solders has caused Japanese electronics manufacturers to resist a change to lead-free solders. JEITA, therefore, instituted a project to establish standards for lead-free solders to be completed by the end of 2003. However, the objective still remains a goal for the Japanese industry in order to comply with the EU's schedule for purchasing only lead-free electronics by 2006 (Metal-Pages, 2003e§).

Scientists at Russia's Institute of Higher Energy Physics reportedly completed the second phase of experiments designed to create new reactor fuels by using lead and bismuth rather than uranium and plutonium. The potential for the commercial development is not known yet (Mining Journal, 2003c).

Bismuth-209, which for decades was believed to be the heaviest naturally occurring atom that never decays, has recently been found to radioactively decay. Its half-life was recently estimated at 19 quintillion (billion billion) years (DeMarcillac and others, 2003; Weiss, 2003).

AlphaMed Inc. (Massachusetts) announced it has received a $500,000 grant to further develop radiotherapy for metastatic melanoma. AlphaMed Inc., in conjunction with the University of Missouri in Columbia, will supply the lead-212 and bismuth-212 generators needed for research into developing a cure for this type of melanoma (Mass High Tech, 2003§).

Work continues on finding an environmentally friendly alternative to lead in small arms ammunition. Alliant Techsystem's ATK ammunition division, producer of 3.4 billion bullets per year, is working to develop a bismuth containing metal polymer bullet. Lead bullets in current use are far less expensive, if one does not consider the environmental cleanup, which can cost three times more than the bullet itself (Metal-Pages, 2003f§).

Nanophase Technologies Corporation has developed a commercial scale process for producing bismuth oxide nanomaterials. This nanoscale material can be incorporated into specialty materials for bone implants and other medical applications. The advantage of this new material is that it is readily detectable by x rays without the toxic and carcinogenic attributes of other heavy metals. When incorporated into plastics, this material also can be used to detect plastic firearms at security stations or the locations of plastic toys if swallowed by a child (Nanophase Technologies Corporation, 2003).

Superconductive Components, Inc. (Ohio) was awarded $518,000 by the U.S. Department of Energy to determine the feasibility of producing bismuth-strontium-calcium-copper oxide (BSCCO) superconducting wires. These BSCCO wires would be used for very high-field magnets beyond 12 Tesla at temperatures of 4.2 degrees kelvin (Advanced Materials & Processes, 2003). This Phase II Small Business Innovation Research grant is in addition to the $105,000 granted for an earlier study and also will be used to investigate the commercial-scale viability of the work (Superconductive Components, Inc., 2003).

Outlook

Indications are that worldwide demand for bismuth is growing at about 5% per year (Metal-Pages, 2004b§). Demand for bismuth in the steel sector, although relatively minor compared with other use sectors, appears to be rising. The chemical sector is increasingly turning to bismuth as Japan increases its use as a replacement for lead in pigments (Mining Journal, 2003b).

International agreements to eliminate lead from solder in manufacturing processes by 2005 in Europe, Japan, and North America will tend to increase the demand for bismuth over the next several years. Many Japanese manufacturers have become lead-free in some or all of their soldering applications, and studies on how best to develop lead-free solders are being performed by the EU, the Republic of Korea, Japan, and the United States, independently (EFSOT, 2004§). In a paper prepared by EFSOT, it was estimated that although overall lead consumption would be reduced by only 0.8%, overall bismuth consumption would increase by about 25% with a move to lead-free solders (Deubzer and others, 2004§). Although metal alloy solders using bismuth and other nontoxic metals are being pursued as a short-term solution to lead-free electronics, research into "smart glues" may provide a metal-less solution in the longer term (Penman, 2003).

Work continues on finding an environmentally friendly alternative to lead that is less expensive than bismuth for use in small arms ammunition. Mitsubishi Materials has developed a new composite material with the same density and hardness as lead. This new tungsten-based material is expected to overcome some of the problems related to bismuth in lead-free hunting ammunition (Metal-Pages, 2003f§).

A significant near-term increase in supplies of lead byproduct bismuth is unlikely because total world production of lead will remain relatively stable and an increasing fraction of lead demand will be satisfied by recycling. Nevertheless, a global shortage of bismuth is not anticipated. In China, where bismuth is a byproduct of tungsten processing, new technologies applied to this resource have increased world bismuth reserves (Werner and others, 1998, p. 54). Therefore, despite any large increases in world demand, Chinese supplies can be expected to help keep the bismuth market stable (Mining Journal, 2001).

It appears that low prices, due to the nearly constant availability of Chinese bismuth during the past decade, constrain bismuth supply to the market. Usually, more bismuth appears quickly in the market whenever prices increase. Thus, it appears that the limiting factor for bismuth supply is low prices, not the availability of the metal (Camak, 1999). As new uses increase market size, growing demand may cause prices to rise. Because Chinese producers could increase production to meet any anticipated increase in demand, stability in prices will require careful management of supplies.

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TABLE 1
SALIENT BISMUTH STATISTICS[1]

(Metric tons)

	1999	2000	2001	2002	2003
United States:					
Consumption	2,050	2,130	2,200	2,320	2,120
Exports[2]	257	491	541	131	108
Imports for consumption	2,110	2,410	2,220	1,930	2,320
Price, average, domestic dealer, per pound	$3.85	$3.70	$3.74	$3.14	$2.87
Stocks, December 31, consumer	121	118	95	111	278
World:					
Mine production, metal content[3]	4,860 r	3,790 r	4,420 r	3,690 r	3,810 e
Refinery production[4]	3,570 r	4,230 r	5,050	4,400 r	4,630 e

[e]Estimated. [r]Revised.
[1]Data are rounded to no more than three significant digits.
[2]Comprises bismuth metal and the bismuth content of alloys and waste and scrap.
[3]Excludes the United States.
[4]Excludes Canada.

TABLE 2
BISMUTH METAL CONSUMED IN THE UNITED STATES, BY USE[1]

(Metric tons)

Use	2002	2003[2]
Chemicals[3]	813	616
Bismuth alloys	1,070	646
Metallurgical additives	388	831
Other	50	25
Total	2,320	2,120

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The U.S. Geological Survey is currently reevaluating the bismuth market; therefore, the end uses for 2003 contain different assumptions compared with previous years.

[3]Includes industrial and laboratory chemicals, cosmetics, and pharmaceuticals.

TABLE 3
U.S. EXPORTS OF BISMUTH METAL, ALLOYS, AND WASTE AND SCRAP, BY COUNTRY[1]

Country	2002 Quantity (kilograms, metal content)	2002 Value (thousands)	2003 Quantity (kilograms, metal content)	2003 Value (thousands)
Belgium	759	$7	10,500	$28
Brazil	999	8	1,800	34
Canada	47,700	458	23,500	363
China	3,000	60	992	9
Costa Rica	--	--	492	4
Dominican Republic	500	35	2,320	294
Egypt	--	--	448	8
Germany	6	5	4	4
Guatemala	--	--	143	4
Hong Kong	332	54	155	28
Hungary	--	35	136	3
Israel	167	22	7	4
Japan	66	26	30,200	2,000
Korea, Republic of	4	6	496	8
Malaysia	9,520	165	--	--
Mexico	34,800	247	33,300	261
Netherlands	5,990	42	--	--
Peru	4,000	50	--	--
Russia	2,070	25	1,510	20
Singapore	150	6	--	--
Thailand	--	--	250	42
United Arab Emirates	58	5	--	--
United Kingdom	20,600	98	1,840	21
Total	131,000	1,320	108,000	3,130

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF METALLIC BISMUTH, BY COUNTRY[1]

	2002		2003	
Country	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
Bahamas, The	684	$6	1,330	$18
Belgium	724,000	5,160	778,000	5,170
Canada	49,800	328	22,500	156
China	393,000	1,760	573,000	3,610
Germany	835	30	67,100	156
Hong Kong	58,500	346	105,000	647
Italy	208	8	500	24
Japan	3,150	152	--	--
Mexico	518,000	3,090	532,000	3,020
Netherlands	102	28	57,900	461
Peru	19,500	121	135	2
Spain	--	--	756	9
United Kingdom	163,000	1,150	178,000	1,130
Total	1,930,000	12,200	2,320,000	14,400

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 5

BISMUTH: WORLD MINE AND REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	Mine 1999	Mine 2000	Mine 2001	Mine 2002	Mine 2003[e]	Refinery 1999	Refinery 2000	Refinery 2001	Refinery 2002	Refinery 2003[e]
Belgium[e]	--	--	--	--	--	700	700	700	1,000	1,000
Bolivia	32 r	23 r	108 r	107 r	100	19 r	14 r	66	65 r	60
Bulgaria[e]	40	40	40	40	40	40	40	40	40	40
Canada[3]	311 r	243 r	258	189	200	250 e	250 e	250 e	250 e	250
China[e]	2,680	1,120	1,250	950 r	1,000	860	770	1,230	700 r	800
Italy[e]	--	--	--	--	--	5	5	5	5	5
Japan[e, 4]	24	26	28	24 r	27	481 5	520 r, 5	551 r	474 r	530
Kazakhstan[e]	130	130	252 r	161 r	150	55	55	130	130	130
Mexico	548 6	1,112 6	1,390 6	1,126 r	1,200	412	1,083	1,390	1,126 r	1,200
Peru	1,000 e	1,000 e	1,000 e	1,000 e	1,000	705	744	640	568 r	570
Romania[e]	40	40	40	40	40	35	35	35	35	35
Russia[e]	50	50	50	50	50	10	10	10	10	10
Serbia and Montenegro[e]	2	2	2	2	1	--	--	--	--	--
Tajikistan	5	5	5	--	--	--	--	--	--	--
United States	W	W	W	W	W	--	--	--	--	--
Total	4,860 r	3,790 r	4,420 r	3,690 r	3,810	3,570 r	4,230 r	5,050 r	4,400 r	4,630

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 4, 2004. Bismuth is produced primarily as a byproduct of other metals, mainly lead and tungsten.

[3]Figures listed under mine output are the metal content of concentrates produced, according to Natural Resources Canada, 2002-03.

[4]Mine output figures have been estimated to be 5% of reported metal output figures.

[5]Reported figure.

[6]Refined metal plus bismuth content of impure smelter products.